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Retro Hardware Renaissance: Reimplementing classic hardware with Field Programmable Gate Arrays

Joe Decuir
IEEE Fellow
jdecuir@ieee.org

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Agenda

- How I ended up at PRGE (again)
- History: three machines
- What is new: modern hardware design
- How can this be used:
  - Atari 2600
  - Atari 800 XL
  - Amiga 500
- FPGA Resources for Makers

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How I got here

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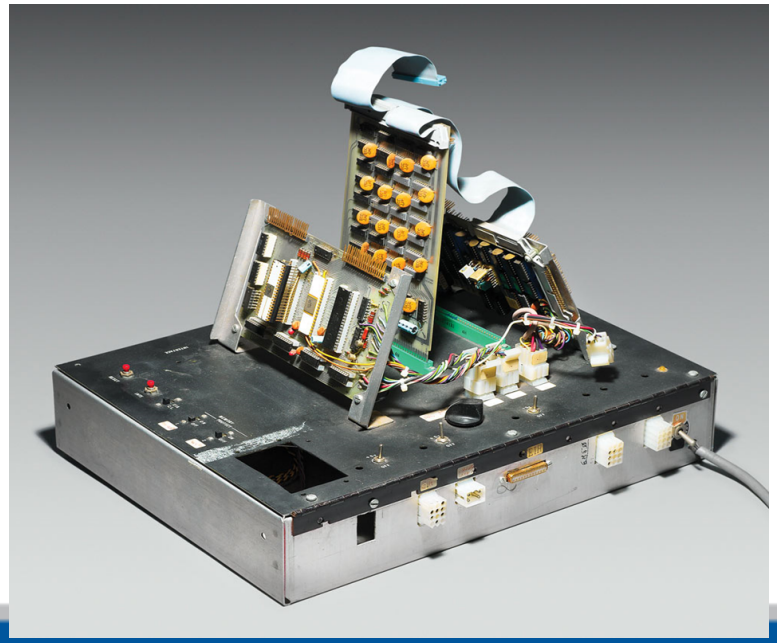
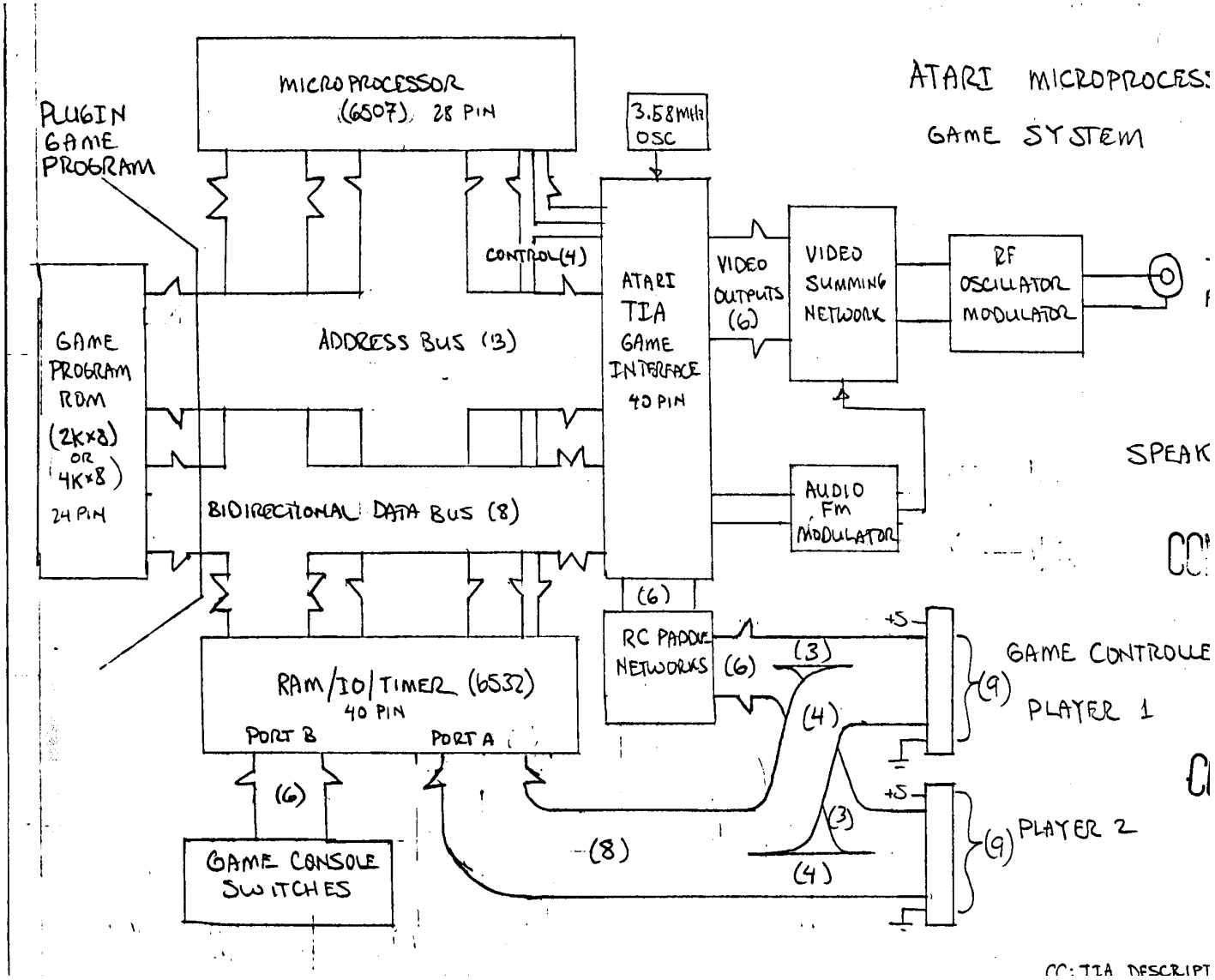
I got lucky: Atari 2600

- I was hired to finish debugging the first concept prototype of the Atari Video Computer System.
  - Most of you know it as the Atari 2600.
- I made several contributions to it.
  - We used to joke about paying to work on it.

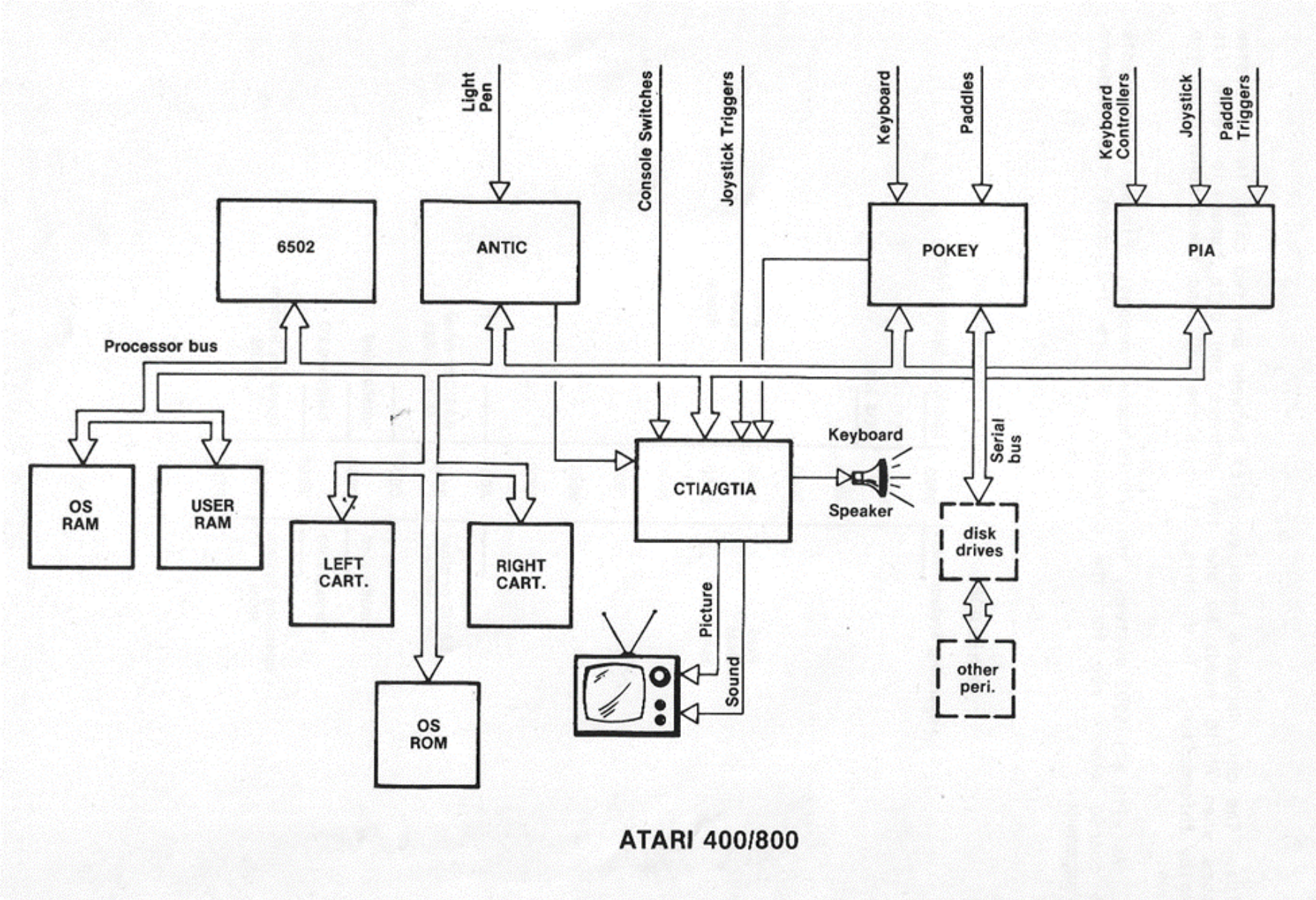


Atari VCS system diagram



Luckier: I got to do it again

- Continue advancing technology.
- We had a hard decision: is the next machine a better game console (Atari 400), a personal computer (Atari 800), or both?

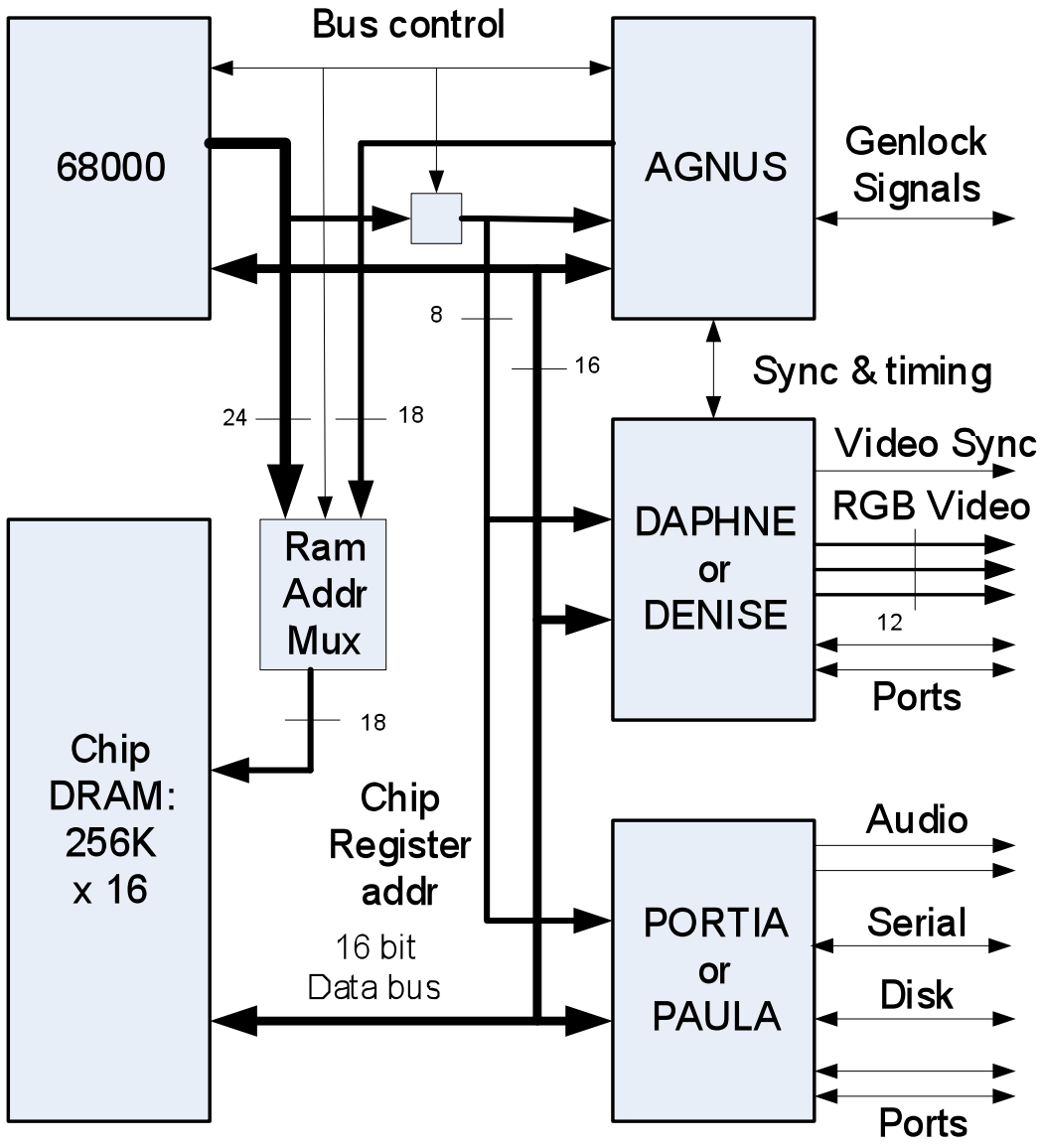


ATARI 400/800

Luckier: we build a 3rd system

- We reunited for a third system: Amiga
- It was a groundbreaking animation machine.

Simplified Amiga Core system diagram



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Modern hardware redesigns: Atari 2600

Retro machines are selling

- There have been several editions of Atari Flashback products.
- Early ones (e.g. Flashback 2.0) were build with Field Programable Gate Arrays (FPGA).
  - Sales of Flashback 2.0 ~ 1M units.
- Newer ones (e.g. Flashback 5.0) are emulated on a small hidden Linux computer.
  - Also, see Retro Pi
- Nintendo is now selling retro implementations of the NES and the Super NES.

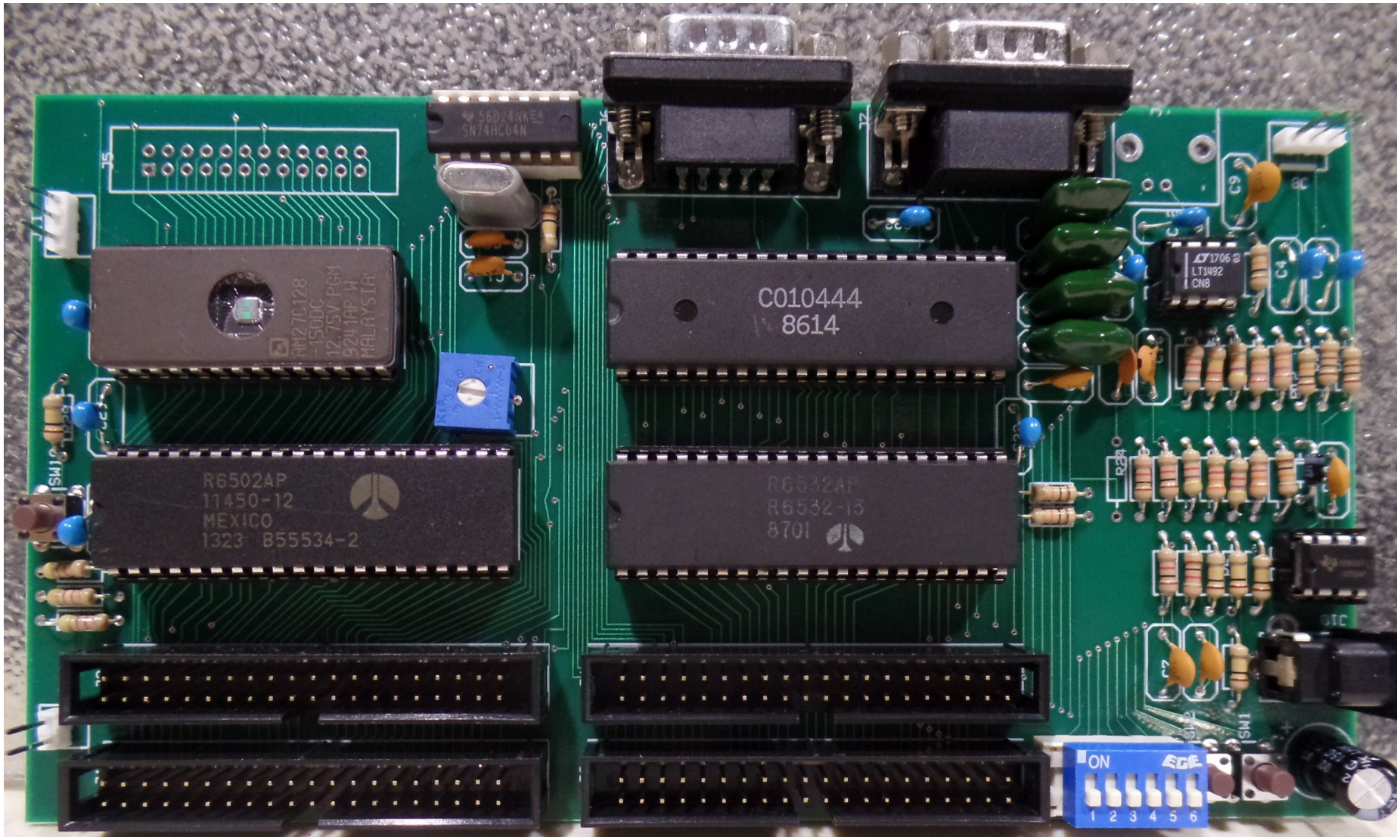
Flashback 2.0 prototype PCB

Curt Vendel

Flashback 2.0 Finished machine

Student Implementation

- As a professor at University of Washington, I get to supervise students in senior projects, called Capstone (EE495-496).
- One group of students started work emulating an entire Atari 2600 with FPGA.
- First project, emulating the 6502.
- The were not successful in the time allocated, but they made progress; they build a subset.
- Subsequent teams will emulate all parts of the system; success = play existing games.



Stuffed Stella Test Board

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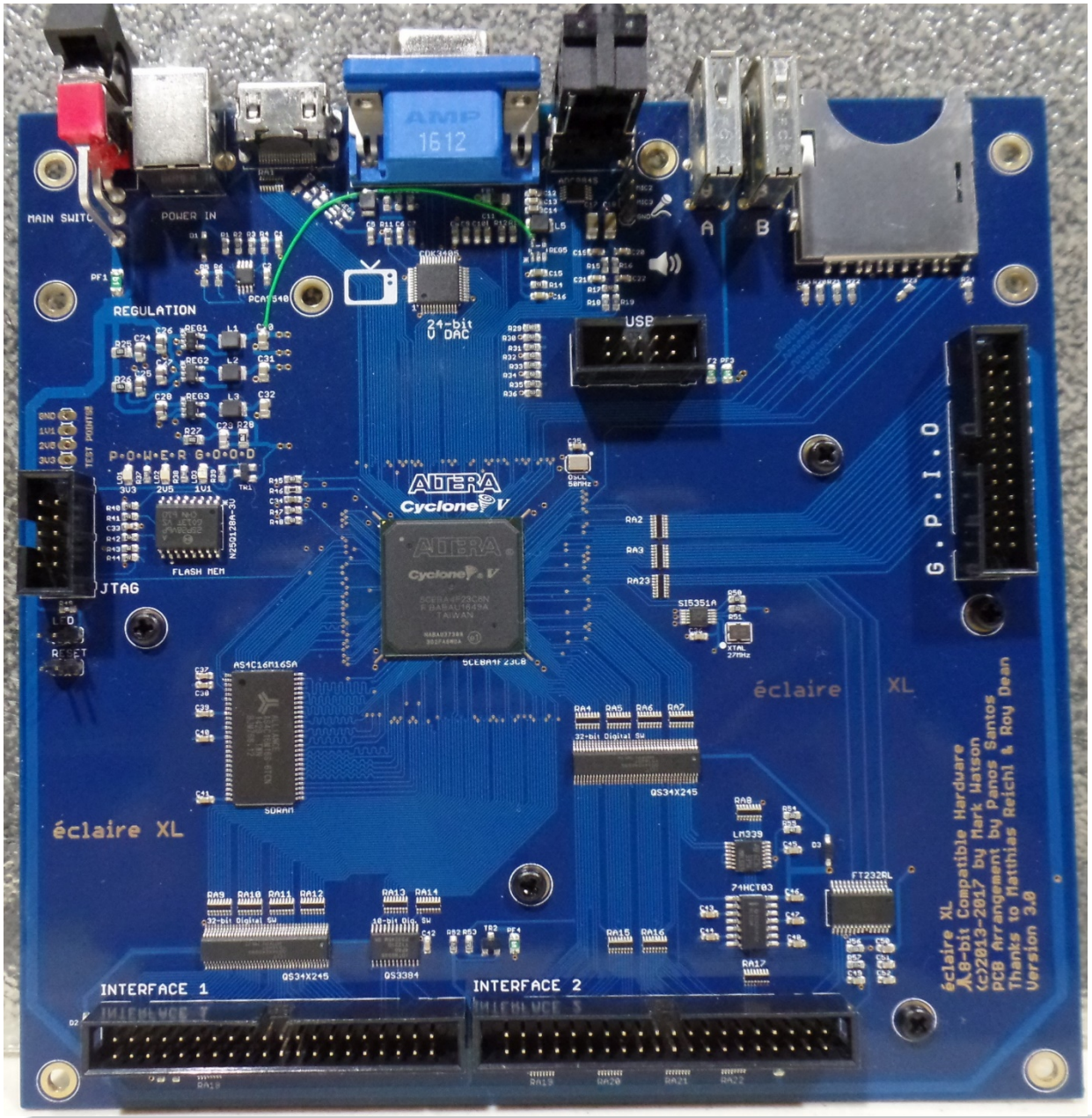
Modern hardware redesigns: Atari 800 XL

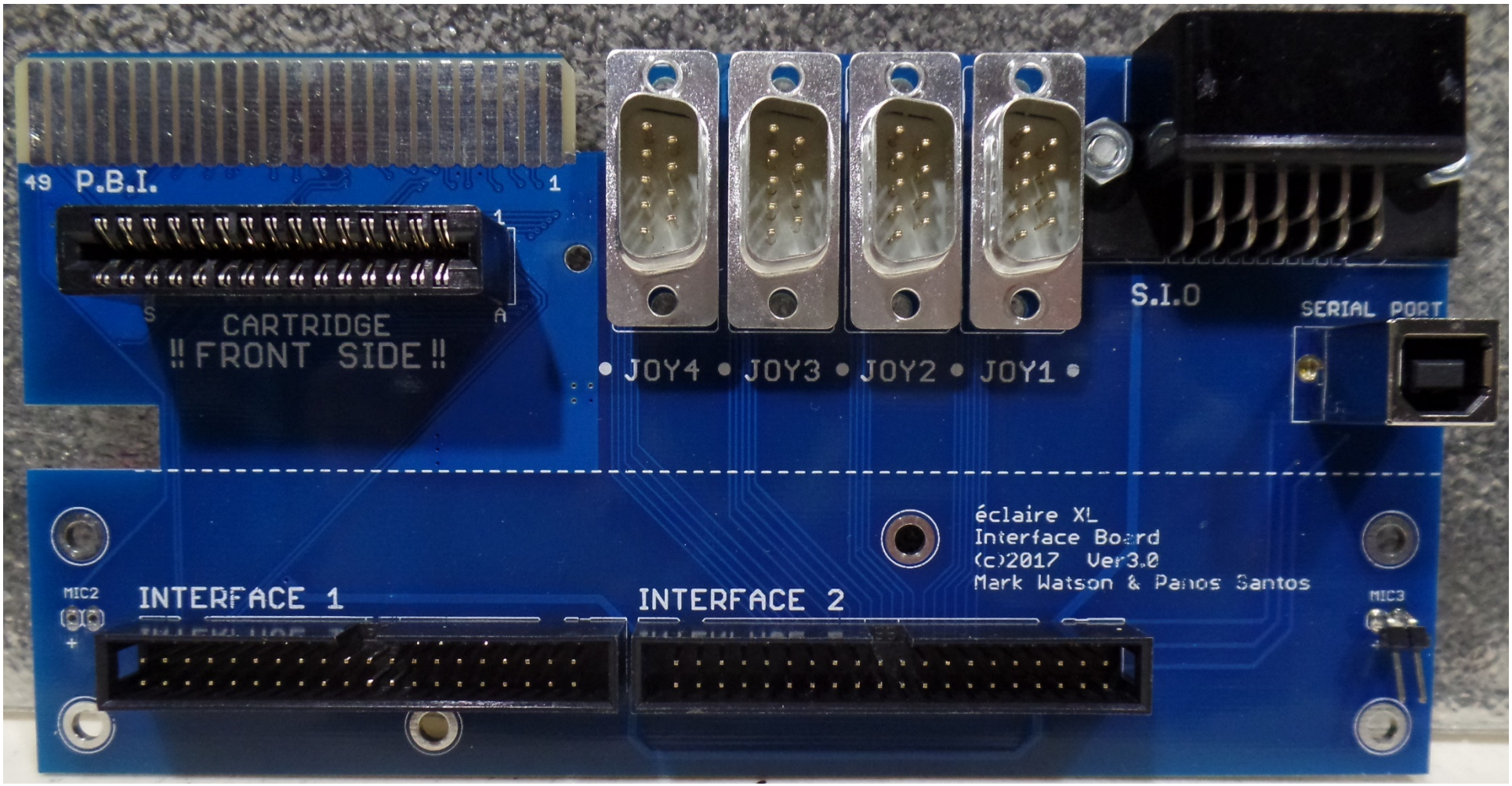
Eclaire XL

- An English engineer, Mark Watson, working with a Greek engineer, Panos, have prototyped and shipped a small number of FPGA-based Atari 800 XL implementations
  - They work with AtariAge
- Differences:
  - VGA video output
  - SD card mass storage
  - USB for keyboard
  - Lots of RAM



Eclaire XL main PCB

Eclaire XL IO board



Eclaire XL FPGA resources

- Mark Watson has been posting design files on http://www.64kib.com/redmine
- Photos: http://atariage.com/forums/topic/263044-developerstesting-required-for-mini-itx-clone-system-eclairexl/
- Nir Dary's demonstration video: https://www.youtube.com/watch?v=ordWyp8HZZ8&t=626s

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Modern hardware redesigns: Amiga 500 MIST

European Amiga redesign

- A Polish designer Przemyslaw Krawczyk (Lotharek") has done a lot of interesting design work: http://www.lotharek.pl/
- The MIST board uses modern hardware to implement classic 16 Bits computers like Amiga, Atari, and 8 Bits systems like C64, ZX-Spectrum, MSX, Atari XL/VCS, Apple II, Colecovision, Sega, NES, etc.
- The MIST is a re-implementation of the original hardware in a FPGA.

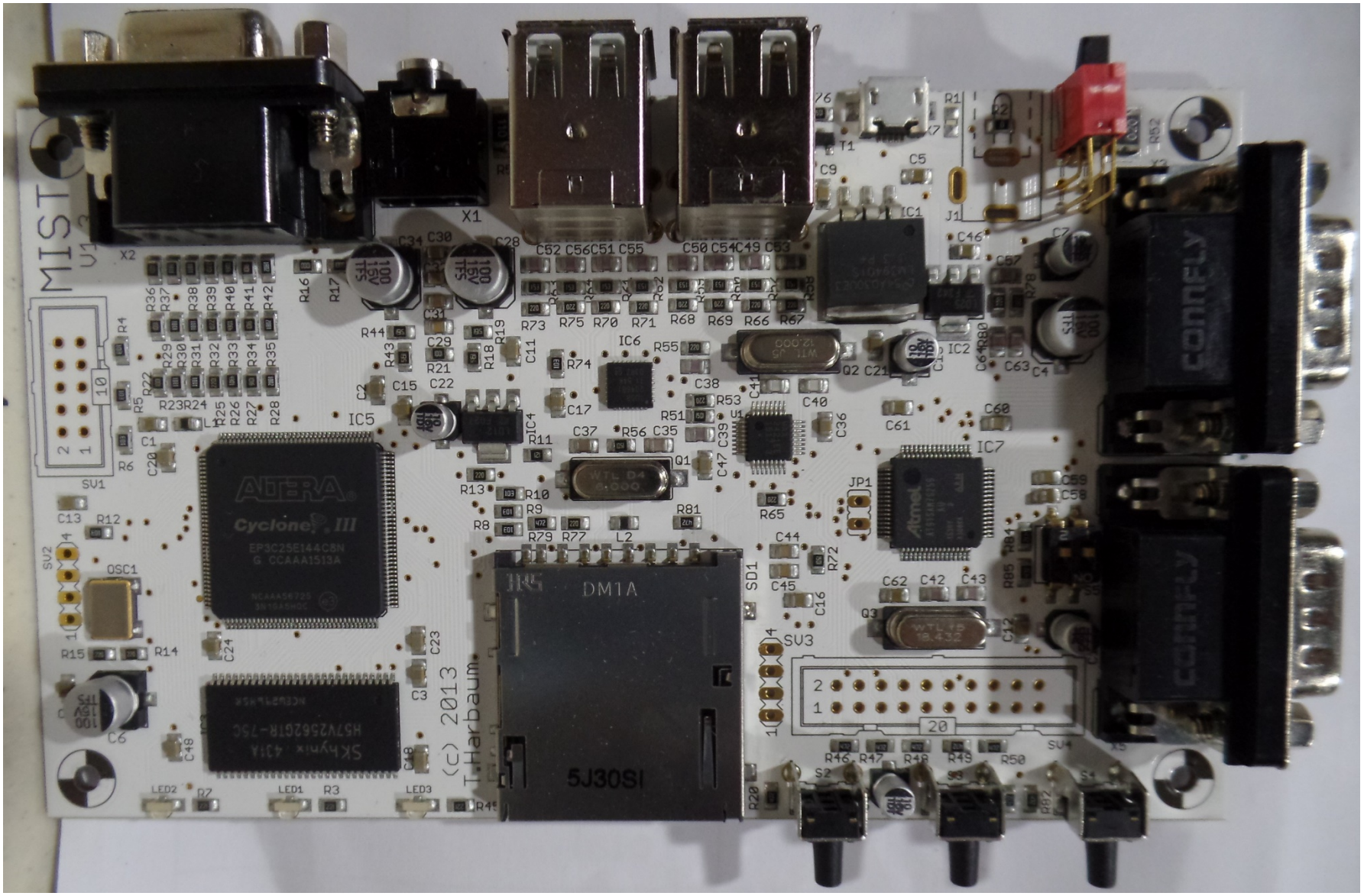
Amiga 500 vs Amiga 500 MIST

- Lots of RAM
- Replace FD (floppy drive) or HD (hard drive) mass storage with SD slot
- Video out on VGA
- Keyboard input via USB
  - 4 USB ports on the back of the device

Amiga 500 MIST device

The front panel has:
- 3 buttons
- 3 LEDs
- SD memory slot

Reverse side:
- Power
- VGA + audio
- 4 USB host



Amiga 500 MIST PCB

Amiga 500 MIST FPGA resources

- YouTube demonstration: https://www.youtube.com/watch?v=9GrmaXeOTEA
- Review of Amiga 500 MIST: https://amigalove.com/viewtopic.php?f=6&t=59
- Firmware: https://github.com/mist-devel/mist-bina
- Tutorial: https://www.youtube.com/watch?v=CVq_jzj_u8U&feature=youtu.be
- Purchase: http://amigastore.eu/en/318-mist-fpga-computer.html
  or
- http://amigastore.eu/en/358-mist-13-plus-midi-fpga-computer.html

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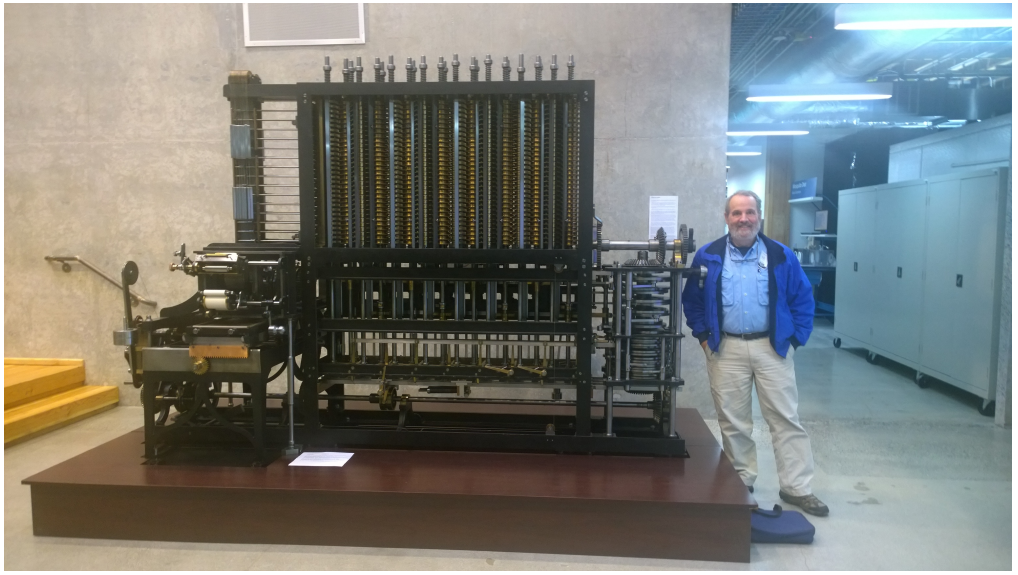
Digital Logic Design and FPGA Resources

Bit of history: digital logic 1

- George Boole invented the mathematics of digital logic in the early 18th century.
- Charles Babbage designed a mechanical version shortly thereafter.

- Ada Lovelace conceived of modern software to run on that system



Bit of history: digital logic 2

- The early 20th century saw digital logic implemented in electronic relays
  - Worked, noisy, unreliable
  - E.g. Bombe at Bletchley House in UK
- Mid-century: vacuum tubes for the early large computers
  - Worked, power hungry, unreliable
- Key: transistors invented in 1947
- Key: integrated circuits in 1959
- Key: TTL in 1964

Bit of history: Digital Logic 3

- People started moving from junction transistors to MOS transistors in 1970s.
  - 1st microprocessor: Intel 4004 in 1971
- Levels of integration exploded.
  - I learned NMOS LSI at Atari and Amiga
- Programmable logic arrays appeared in the 1980s.
- Field programmable gate arrays were invented in the mid-1980s, and became popular in the 1990s.

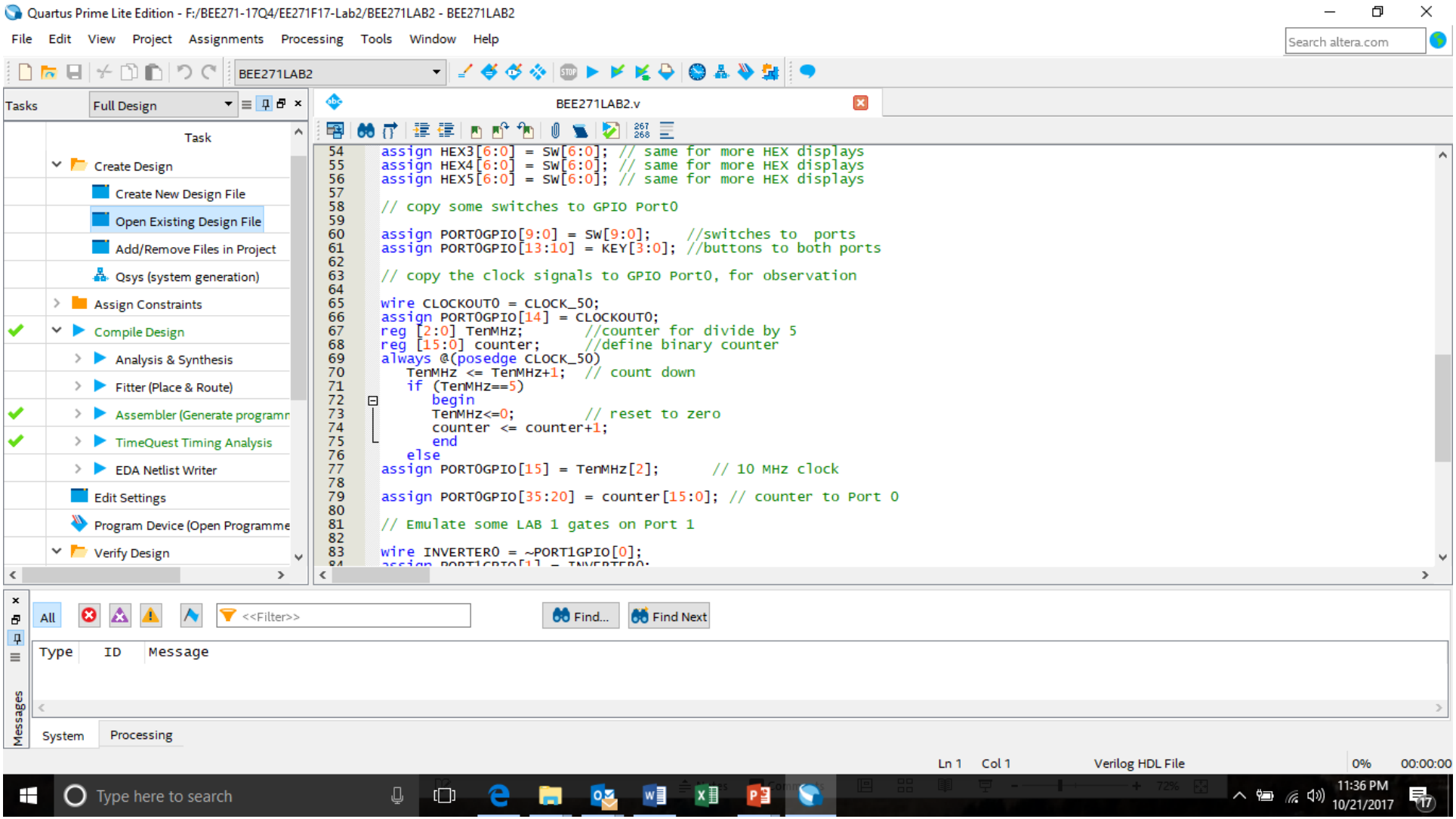
Modern hardware design

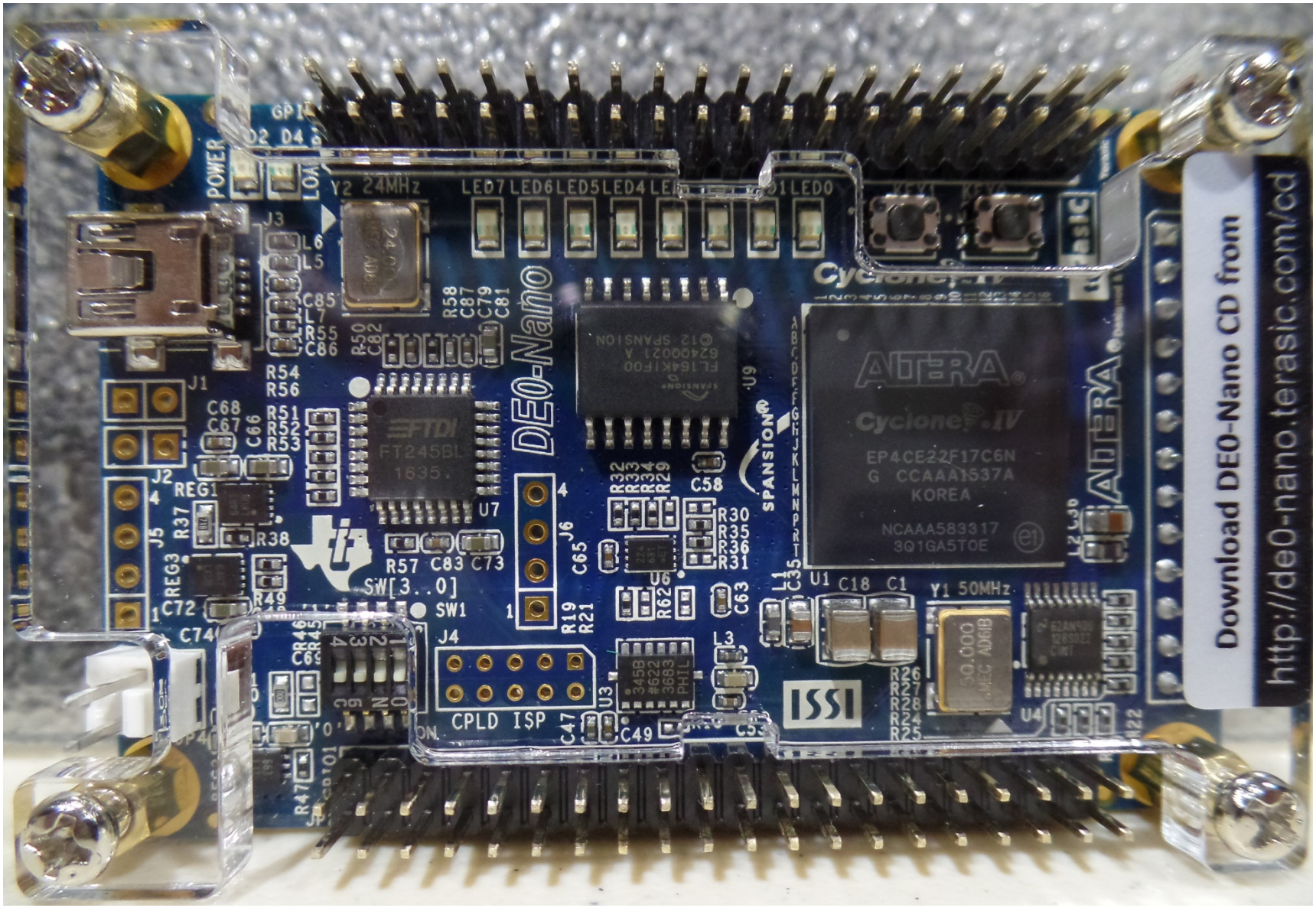
- Modern universities teach digital hardware design using hardware design languages:
  - VHDL (IEEE standard 1163)
  - Verilog (IEEE standard 1364)
- Two big reasons:
  - Easy to prototype and revise
  - Simple path to full custom ASIC from debugged FPGA
- Biggest vendors:
  - Altera (now Intel)
  - Xilinx

FPGA Resources:

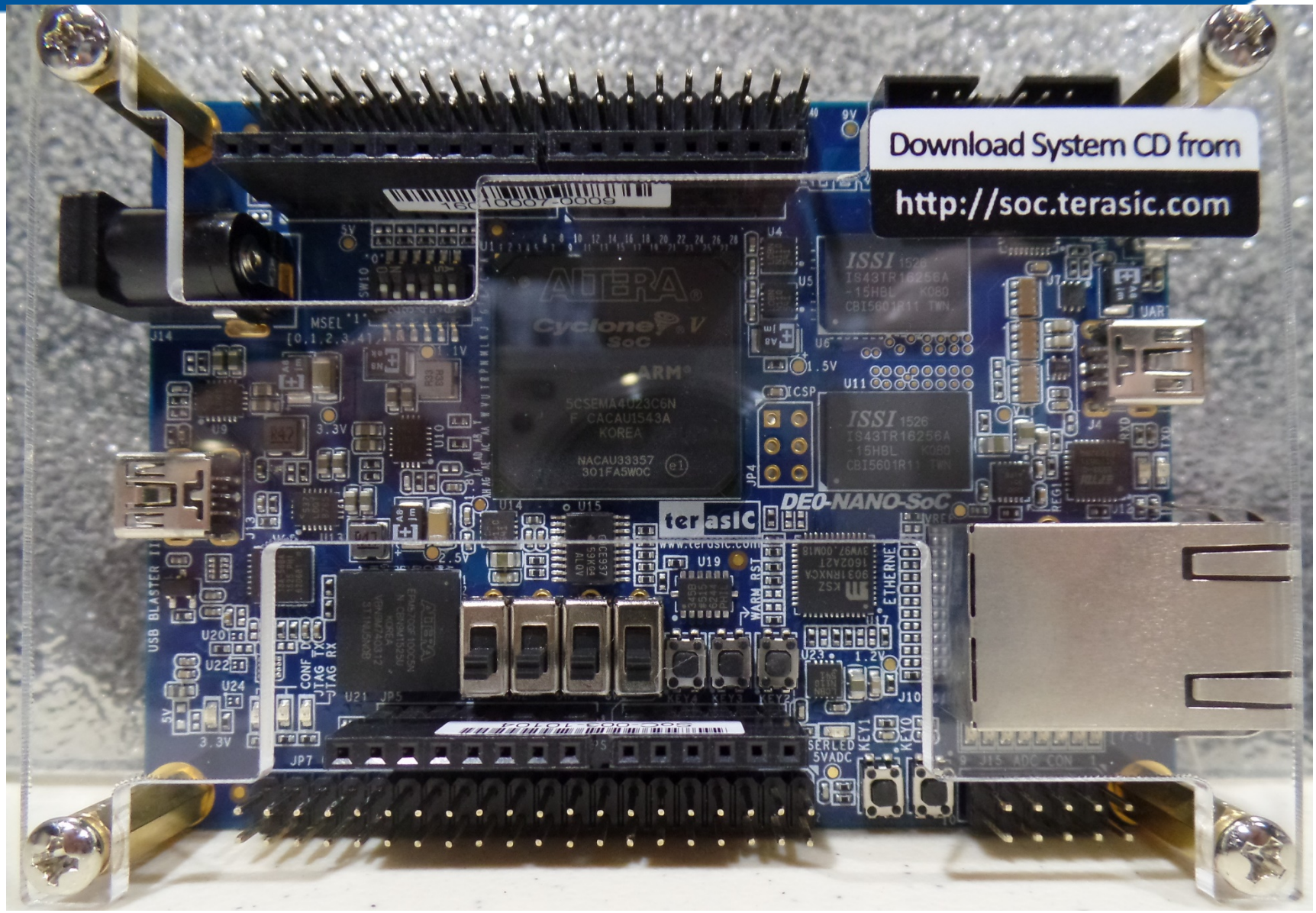
- Standard textbook: Fundamentals of Digital Design with Verilog
  - 3rd edition is current, and cost over $200
  - 2nd edition is cheap
- Free compiler software: Quartus Prime Development Suite, 16.1 or later
- Terasic FPGA kits:
  - DE0-Nano: pure FPGA, under $100
  - DE0-Nano-Soc: FPGA plus embedded ARM
  - DE1-Soc: larger FPGA plus embedded ARM

Quartus Screenshot

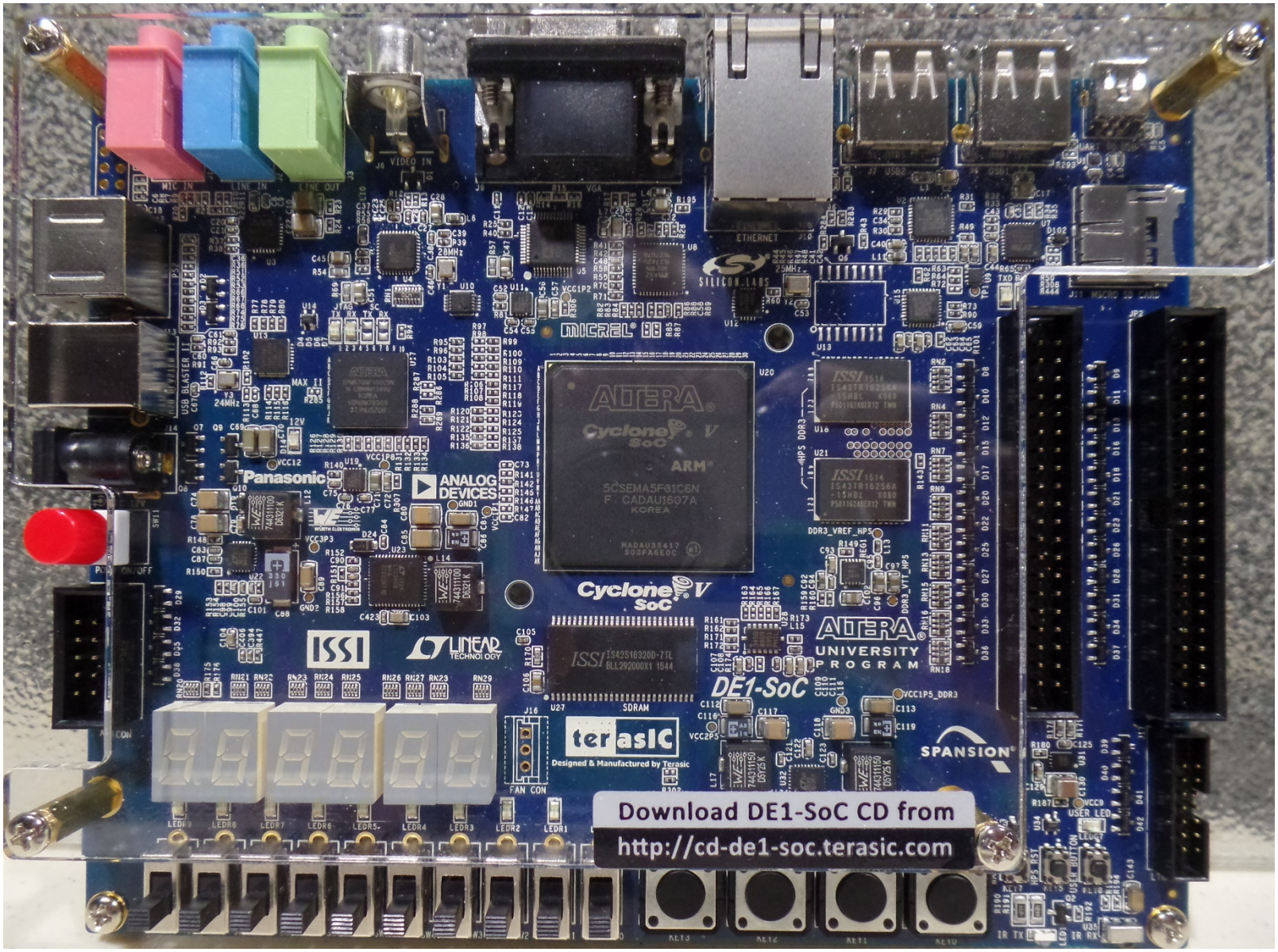




Terasic DE0-Nano



Terasic DE0-Nano-SoC



Terasic DE1-SoC

What can you do?

- Learn something new
- Today, electronic hobbyists can learn to program in many languages, build systems with Arduino devices, Raspberry Pi devices, etc.
- You can build circuit boards.
  - E.g. use ExpressSCH and ExpressPCB
- This is new: learn cutting edge design

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Resources

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My contact information

Joe Decuir

Issaquah, WA USA

IEEE: jdecuir@ieee.org

IEEE Fellow

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Global Humanitarian Technology Conference

Editor, IEEE P2030.10: DC Microgrids

Work: jdecuir@uw.edu

Lecturer, University of Washington

In memory of Jay Miner 1938-1994

Questions?